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ABSTRACT

Two studies (which followed up a 4-year longitudinal study) examined the impact of hypertext on students' learning in science and English classes. The first study compared the impact of HyperCard stacks and regular textbook presentations of ideas in biology on ninth-grade students assigned to study these materials. Students in the second study, 10 ninth- or tenth-grade students, developed their own HyperCard stacks and regular texts for projects in science and English courses. Data included interviews, videotaped observations of project development, and outcome and process measures. Results indicated that (1) students suggested that the hypertext offered alternatives to standard print texts; (2) students considered HyperCard projects more interesting than conventional texts and assignments; (3) HyperCard texts create by students contained more main ideas, enlisted more illustrations, were more multilayered, and provided clearer links between illustration and the text; (4) hypertext allowed a flexible exploration of ideas across several layers simultaneously; (5) students were motivated to explore its possibilities and were willing to share new findings with other students; and (6) the use of hypertext supported the acquisition of complex ideas and relations between those ideas involving science tasks, but not, apparently, those involving English tasks. Findings suggest that students view the advantages of the hypertext as allowing a way to "architecture" a space that affords different engagement for others. (Contains 16 references and 4 tables of data; appendixes contain a total listing of student interview questions, and an example of a debriefing interview analysis summary chart.) (RS)

Assessing the impact of hypertext on learners' architecture of literacy learning spaces in different disciplines: Follow-up studies

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Note: After reading this article, please visit the online discussion forum and share your comments.

Introduction

> Hypertexts remind us that acquiring the discipline to organize one's thoughts into a linear, hierarchical argument is a large part of what we call literate only because the technology of print does not invite other ways to structure and argument, not because that is the natural way we think. Hypertexts provide a means to express ourselves in ways that reflect more directly the complexity of our thinking and the interrelatedness of ideas. (Reinking, 1994, p. 24)

> [Hypertext] allows authors and groups of authors to link information together, create paths through a corpus of related material, annotate existing texts, and create notes that point readers either to bibliographic data or to the body of reference material. Hypertext can allow the creation of an automated encyclopedia of sorts: readers can browse through linked, cross-referenced, annotated text in an orderly but sequential manner. (Yankelovich, Meyrowitz, & van Dam, 1985, p. 18)

As students create texts, they develop spaces for themselves and others. Just as an architect designs spaces in concert with the resources in hand, the environment, and certain goals, learners are constantly engaged in spaces that they create from their resources, frameworks, machinery at hand, and goals. As Vygotsky (1978) suggested, tools such as language or other sign symbols mediate our interactions with the world.

In recent years, with the advent of computers and innovative software, enormous strides have been made in the evolution of textual spaces. Among the most intriguing advances has been the generation of software that allows for the development of texts that are multilayered, multimedia-based, and nonsequential -- text that appears to have the potential for changing how we learn, what we learn, and the nature of community and communication.

Uses of authoring systems

In many ways, the advent of new authoring systems reminds us that literacy is a technology that may support certain ways of knowing over others and support certain conventions or norms of interacting. In particular, with the advent of hypertext, students have access to an authoring tool that allows for the following:

- unfolding ideas through buttons, scrolling, and other means by which authors can stage when and where ideas are displayed;
- creating links between ideas (for example, embeddings) that allow for various forms of relationships: definitional, illustrative, or critical, such that compositions or textual spaces are, as Bolter (1991) has argued, "pulsing networks of ideas";
- providing the dynamic and graphic presentation of ideas by interfacing alphabetic texts with nonlogocentric media such as graphics, animation, or video;
- supporting access to resources and their incorporation in ways that are both malleable and complex;
- furthering a relationship with readers that is collaborative and portfolio-like as stacks

offer multiple layers and multiple explorations and engagements;
- affording asynchronized access to ideas and communications;
- supporting the development of architectured spaces that afford these multidimensional possibilities and a different form of participation by users.

Background

Many of us have been participant observers in the advent of hypertext technologies in conjunction with excursions to Web sites, attempts to create our own sites, or what we have encountered on television (such as multilayered graphic displays used in the evening news or coverage of sporting events). For some of us, the advent of this technology occurred as we worked in school settings -- including settings engaged in exploring the use of technology including HyperCard, hypertext software created by Apple Computer. For example, in our work in the Apple Classroom of Tomorrow (ACOT) we were eyewitnesses to students' introduction to hypertext. In this role, hypertext reoriented our view of the literacy and our views of the impact of technology on learning. We were in year 2 of our 5-year longitudinal study (Tierney et al., 1992) when hypertext was introduced and became the platform of choice for the students' projects.

Students embraced the multimedia and multilayered possibilities and the ability to control the presentation of ideas. As one student suggested, texts were "no longer boring, but dynamic" and conversations around stacks overflowed to recess as students gathered around and critiqued one another's texts with the same attention they might give a video game. In these conversations students assumed roles similar to what one might envision occurring at a meeting of architects -- asking one another, "How did you do that?" "Where did you get that material?" "Can I borrow that?" and "I might modify and use that in my own project."

New learning spaces

As we examined our interviews and observations of students across the 4 years, the advent of hypertext marked a shift toward the development of new learning spaces. We became fascinated with these new spaces and the shifts that they encompassed: the multilayered renditions that were created, the dynamic graphic interfaces enlisted, and the view of audience and meaning making that were sponsored. In years 1 and 2, the students' texts were linear and largely devoid of graphics, whereas in years 3 and 4, graphics had become an integral symbol system within the students' texts; their compositions no longer were one-dimensional, but were multilayered and interactive. Several major shifts occurred as students experimented with these new compositions, especially the graphic interface and multidimensional possibilities that they afforded. The shifts were captured in self-initiated comments and in comments students made when we probed them.

For example, in year 1, interview comments suggested a very linear approach to the text. Comments such as the following were typical:

> It [the computer] helps you to just write down, or type out what you're thinking about, and then lets you get the rough idea out, and then you can just go back and change or add to it. [audio file: 100k]

> It's better to do it on the computer because instead of retyping the whole story you can just add in and correct your mistakes. [audio file: 100k]

With the advent of HyperCard, student descriptions of their approach reflected different goals, different architecture, and different expectations for their text.

> The things that we created weren't really something that could be done on a page. They could be printed out but they still wouldn't be the same, clicking on a button. It wasn't something you could look at; it was something you had to become involved with.

> I wanted to use graphics for this because I don't like to use a lot of text for a project, for anything I do. As I noticed whenever, that is, it tends to get real boring. Even when I have text sometime I like to spruce it up with graphics, at least make it look interesting because I try to make it so that if I had to look at this it wouldn't be something that I would think I had to do. It would be something I was doing because I wanted to. That was one of the concerns when I was doing that paper that we just had. For me it was a bunch of editors and writers and we wanted it to be something that people would enjoy. They would want to read. You can see how it developed.

> But whenever I want a stack I try to make it more interactive so that there's a lot of things that the person who is using them might not see going on. There's variables being changed and carried out and all these things.

Follow-up investigations

In hopes of providing some clarity of the impact of hypertext we decided to pursue some follow up to our interviews in the form of some additional exploratory research -- namely, two investigations.

Follow-up: First probe

Our first probe or investigation (see Galindo, Tierney, and Stowell, 1989, for more details) compared the impact of HyperCard stacks and regular textbook presentations of ideas in biology on students assigned to study these materials. Ninth graders enrolled in the Apple Classroom of Tomorrow were presented with HyperCard stacks and textbook chapters dealing with topics in biology. The textbook chapter represented a traditionally formatted treatment of a topic with subsections together with an occasional illustration; the HyperCard stack afforded multilayered treatments of the same topic (using the same material) in a fashion that used buttons to connect students to illustrations and definitions.

Individual interviews were conducted with the ninth-grade students. In the first part of the interview, the students were asked how they would study the biology chapter and then the HyperCard study guide for a test. This was followed with observations of their behavior as they studied the same information presented in HyperCard and in a biology text. In the second part of the interview, the students were asked what they thought were the advantages and disadvantages of the biology textbook material and HyperCard stacks. In

the third and final part of the interview, the students were asked to compare writing with HyperCard to a regular written assignment.

Analyses of the student interviews were driven by the following questions. First, what is the nature of the communicative framework across the two types of representations of information: a regular textbook and a HyperCard text? Second, what is the nature of the knowledge acquired by studying a regular textbook versus a HyperCard text? We examined statements students offered about what ideas were accessed and how such ideas were linked. Third, what were the students' learning strategies for HyperCard as contrasted with those used with the regular text? In particular, student comments and observed behaviors were examined in hopes of defining the procedures enlisted to access ideas in reading and writing regular text and a HyperCard text.

Follow-up: Second probe

In our second probe or investigation we pursued these issues further. Students in our second investigation developed their own HyperCard stacks and regular texts across parallel topics in two subject areas. As we attempted to study more closely the impact of hypertext on learning processes and outcomes, we enlisted a design, including various measures that might yield more information on the impact of hypertext on the learning of individual students across topics and disciplines (English language arts and science). The following were among the questions that were addressed: In what ways do hypertext-based versus regular text-based compositions vary ? To what extent do these differences vary across individuals of different expertise across selected subject areas (English and science)?

For the second investigation, we enlarged our pool of students involved to 10. All of the students were volunteers and were paid for their participation, which involved extended periods of time each day (3 to 5 hours) across a 3-week period in the summer. During this time, the 10 ninth and tenth graders were involved in developing projects in science or English on different topics. All were competent computer users, but varied in their ability with hypermedia. They included two African American students, two Asian American students, and six Euro-American students who had exposure to hypertext in their classes and some limited use of the software.

Students were assigned randomly to either science or English. Within those subject areas, students were rotated randomly through regular and hypertext-based projects on parallel topics. In geography the topics were "deserts" and "the ocean." In English the topics were "unsolved mysteries" and "unanswered questions." To support the students, a range of resources including books on the topic were available. The students had access to scanning as well as laser-disk technologies, and we enlisted older students to provide technical support (to assist them with their set ups). As with the first investigation, data collection consisted of taped interviews, videotaped observations of project development, the projects themselves, and some outcome and process measures (a measure of shifts in background knowledge and a measure of problem solving).

Data analysis

We pursued various analyses of the transcribed interviews, the compositions themselves, and the learning strategies and outcomes that were prompted. Data for the first

investigation were drawn from our observations and interviews of the students who were asked how they would study the biology book chapter and then the hypertext study guide and were observed doing so. This was followed with an open-ended discussion of what they thought were the advantages and disadvantages of the biology textbook and hypertext study guide as well as what they felt would be the differences involved in composing these texts. In the second investigation, students actually developed hypertext and regular text compositions and responded to a range of measures and a lengthy interview. The interview involved an extensive discussion tied to a total of 30 questions that were asked (see Appendix A for sample of these 30 questions). These questions and the responses were later categorized according to similarities and differences between the two modes: learning outcomes, the approach, observations, the impact of written text, use of resources, interviews and pre- and posttest measures, the writer, ideas, the response of other students, reactions and suggestions about the projects, and personal learnings.

Transcribed student interviews were placed in a Macintosh database management system called FileMaker II. Each student's response to specific questions was sorted and transferred to the same file so that comparisons could be made across students. Student responses to the questions, arranged in the major categories mentioned, were further narrowed to phrases and placed together according to related themes. In addition, comparisons across students and disciplines were charted. (The questions for the second investigation are presented in Appendix A together with a sample of how the analyses were pursued.)

In the second investigation, analyses of the background knowledge, problem solving, and the actual compositions also were pursued. Details of these analyses will be provided with the reporting of results in the following section.

Results

Author to text

The data we acquired from our two investigations confirmed the longitudinal trends that we had observed. In the first investigation, the students suggested that the hypertext offered alternatives to standard print texts ("There were other ways to present ideas" "...drawing pictures...making buttons...going to different stacks") and commented that to do so was more demanding but worth the effort. Similarly, the students involved in our second probe suggested that hypertext afforded them possibilities that traditional text did not. Tables 1 and 2 detail the comments of the students in conjunction with some of the discussion that ensued pertaining to text features. (E stands for English, S for Science, HC for HyperCard, RT for regular text, and B for both.)

Table 1

As the responses in Table 1 indicate, the students view of the composition possibilities differ and seem tied to (1) the graphic interface possibilities (see items highlighted in green) and (2) the perception that the hypertext restricts text (see items highlighted in purple) to what can and should appear on a screen. It should be noted that the brevity was deemed consistent with their desire to focus on the important information (see items highlighted in

orange). The students felt as if there would be greater interest in a project when only important information was given. In contrast, traditional text projects were viewed as merely writing production (see items highlighted in pink). That is, students just write and have plain text, something that they have seen time and time again over their years in school. One of the students involved in the science projects (labeled S-5) described the nature of the text differences:

> You can write in both of them and you can tell a story and you can get your point across but the differences are that you can get your point across in different ways on HyperCard and in text you just write. In HyperCard you can have a picture there with it. You can have buttons. You can have animation even. You don't have to write. [audio file: 200k]

Table 2

As Table 2 shows, when asked about similarities and differences between HyperCard and regular text projects, all 10 students stated that HyperCard is more interesting, more enjoyable, more exciting, or better than more conventional writing assignments. In addition, 5 students described regular text projects as boring. Even though a total of 9 students felt that HyperCard takes more time and requires more work, only 1 student showed a preference for working on regular text projects.

Table 2 (continued)

When students were asked about the approach to projects, prior organization and planning were valued as important components in the implementation of HyperCard projects for 7 out of 10 students [see Table 2 (continued)]. They felt that HyperCard required energy and time resulting in higher quality products. Pride in their accomplishments seemed to follow this greater investment. The creation of buttons, animation, graphics, and fields were elements that increased the difficulty of HyperCard, yet at the same time increased pride in meeting the challenge that HyperCard presented.

Table 3

Overall, all 10 students felt that they could express their ideas in either mode, but HyperCard afforded more possibilities (see Table 3). These included such options as manipulation (see items highlighted in pink), separation of text (see items highlighted in aqua), and animation (see items highlighted in brown). The separating of text required by HyperCard allowed for manipulation of form and increased freedom to experiment with different aspects of presentation (such as space, movement, or switching pictures). To these ends, the students appeared to rely more on past experience for English topics; for science topics students relied heavily on the resources provided, especially graphics.

Advantages of hypertext

In some ways the aforementioned observations of students seemed to suggest what may be obvious attributes or possibilities of hypertext software. Hypertext clearly supports

multilayered multimedia possibilities that are less likely to be engaged by students pursuing traditional text forms.

Certainly, regardless of subject area (English and science), HyperCard texts created by the students contained more main ideas (that is, greater written detail was evident in all conventional texts), enlisted more illustrations, were more multilayered, and provided clearer links between illustrations and the text. In terms of level of detail, the hypertext compositions of the students included less information than the regular text compositions. Again students tended to limit the hypertext to the important ideas that could fit onto a single screen. In addition, it should be noted that rather than relying on text, students involved with HyperCard projects were able to develop a sequence of events by the movement from card to card, and were thus able to avoid overly detailed texts.

When English and science were compared, the hypertext compositions produced in response to English-related topics were far more detailed and elaborate than were the science texts, which were primarily a listing of facts. Science pieces, both conventional and HyperCard, contained noticeably more main ideas than did English.

Artwork and illustrations were far more apparent in the science projects and provided a larger contribution to the text than did the illustrations in the English projects. Again, this may have been a reflection of the nature of the science content All the students who used illustrations appeared to incorporate them in a logical sequence. Science projects not only discussed desert animals, they provided an immediate illustration of the animal it its natural habitat. The science HyperCard projects also appeared to be more multilayered than did their English counterparts; the science projects appeared to focus on the delivery and explanation of ideas. Alternatively, English pieces contained far more supporting ideas and appeared to emphasize the unfolding of their text to heighten suspense. English texts used visuals to orient the user or reader to a certain perspective as well as to heighten involvement. An English HyperCard project established a link between the third-person voice and the first-person view of the illustrations, providing a richer experience for the reader.

Author-reader and student learning

In discussing technology and learning -- especially with the World Wide Web -- Owston (1997) emphasizes that "no medium, in and of itself, is likely to improve learning.... The key to the Web appears to lie in how effectively the medium is exploited" (p. 29). We would posit that the Web is an extension of hypertext and moreover would suggest that hypertext as a learning and communication tool also is contingent on how well its features lend themselves to exploitation. The students we interviewed and observed seem to suggest that this tool affords opportunities to engage in ways of connecting ideas that otherwise would have been less possible with traditional texts.

As we suggested in the introduction, hypertext allows for flexible exploration of ideas across several layers simultaneously. The set of navigational tools available to the developer allow for the development of intertextual linkages that suggest a view of the reader's engagement that is both multimodal and multilayered as well as menu-like. Likewise, readers' involvement and choices are apt to expand as they are faced with decisions that they are expected to initiate. Indeed, the role of readers may increase the

likelihood of reader engagement that is less acquiescing.

The multimedia possibilities appear to serve a motivational function as well as alternative ways of learning that afford the kind of learning by metaphor or semioses that Siegel (in press), Siegel and Carey (1989), and Labbo (1996) have suggested. For students across both investigations, a combination of reading, viewing, and listening, and aspects of a HyperCard presentation seemed preferable to regular text presentation. They felt that multimedia presentations contribute to the respondents' engagement with the product (i.e., they will read it all, are more drawn to it, pay attention more, listen more, and watch it more), thus increasing the possibility of personal understanding [see Table 3 (continued)]. Student S-5 supports these ideas with the following response:

> Text just -- when you learn something new in the text I don't think it's as interesting. Now in HyperCard I think that that is really good because when people talk I like it a lot when you can see something like when they have an animation. I think that really catches your attention because you see something on the screen and you're like what is that? It's really cute and it gets your attention and with text you're just like oh, and you have to sit and listen and I can't sit and listen for a long period of time because then I'm like -- I kind of want to drift off but with HyperCard there are so many ways that you can catch their attention and so it makes you remember more.

Table 3 (continued)

Above all, HyperCard was considered more enjoyable to students because it was novel; it drew attention and thus caused the students to investigate its operation. Students seemed moved to explore its possibilities and were willing to share new findings with other students. Regular text projects, however, were considered less exciting because they were more traditional and less innovative, and the students had used the mode for many years.

Certainly, hypertext and the Web may offer users the advantage of working in a genre that gives the author more license to create new forms of discourse. As Nyce (1987) suggested, hypertext has yet to have in place established conventions. He stated, "how knowledge should be represented and created remains an open question" (p. 186).

Indeed, our students' speculations concur with findings from our attempts to measure shifts in knowledge and problem solving more directly.

Impact on students

Assessing the impact on learning outcomes versus self-reports of their impact prompted us to pursue the difficult job of examining changes in learning through the enlistment of several additional measures. To these ends, we pursued some additional data collection beyond our interviews· student responses to (1) a "real problem," (2) an ambiguous text, and (3) a background knowledge assessment. These tasks were removed from the project itself, in that they were asked out of the context of the HyperCard or nonHyperCard projects, and thus were analyzed separately. For the knowledge assessment, the students primarily listed everything they could remember about the assigned topic; however, several students wrote in sentence form and one or two wrote more elaborate paragraphs. The

nature of the prompts in the real problem called for entire sentences and questions, and, as a result, the students presented a sequence of topic-related statements, often in the form of a question. Two researchers evaluated each student's responses in terms of number of ideas, complexity, and flexibility. Inter-rater reliability was judged to be approximately 90%. Analyzed characteristics were defined as follows:

x number of ideas:	number of separate ideas expressed by students
x complexity:	ideas were elaborated on by the student -- ideas were clarified further -- for example, subordinate clauses and adjectives were present. Complexity was rated 0, 1 (at least 1 instance of complexity), or 2 (2 or more instances)
x flexibility:	classes of ideas were identified by researchers, animals, plants, or survival, to name a few

Ambiguous passages were used to measure the impact of hypermedia on an individual's ability to generate and link ideas. After reading the selected passages, 10 students responded in writing to four questions: (1) What questions do you have about this passage? (2) What do you think is happening? (3) What do you think happened just prior to this? and (4) What do you think happened just after this? The open-ended quality of each passage allowed for multiple interpretations and varied responses across individuals. In the English topic group, there were three distinct passages administered during the beginning, middle, and end of the study. In the science topic group, a total of six tasks were used involving four distinct ambiguous passages. Prior to and following the first project (HyperCard and nonHyperCard), the same passage about deserts was read and responded to by the students allowing a pre- and posttest measure. The third task involved a different ambiguous passage on deserts. This sequence was repeated using the same ocean passage for the fourth and fifth tasks followed by a different final ambiguous passage on oceans. We focused primarily at the two instances when the passages were repeated. Our overall purpose for administering these tasks was to look for shifts in the presentation of ideas and how the ideas were related to one another.

After reviewing the students work, we became particularly interested in the difficulty of questions asked, the amount of students' ideas, the links between ideas, and the flexibility or classes of ideas represented in each student's responses. As a result, the analysis of students' responses to ambiguous passages followed two directions: an ideational analysis of responses using three categories: (1) total number of ideas, (2) complexity of ideas, and (3) flexibility; and number of classes of ideas. Again, these three characteristics were examined in terms of differences between HyperCard and nonHyperCard measures.

Our analyses of these data created more questions than answers. English and science, not surprisingly, seem to reflect two very different disciplines and hence ways to approach tasks. Therefore, English and science tasks will be discussed separately.

English tasks

By the nature of the content area of English, there are no real "facts" to acquire, and the nature of the task itself depends on one's own prior experience and knowledge. Shifts in the

areas considered might depend more on the involvement of the writer than on any experiences gained through reading or the use of media (HyperCard, nonHyperCard). The measures used might fail to capture changes that occurred in the individual student. A description that states the existence of complexity, for instance, fails to measure the subtle differences between student E-1's pre- and post-responses to "answered questions":

> pre: Questions are the only reasons we are willing to go on living from day to day.
>
> post: Makes you feel conscious about the world you live in.

The same trends were apparent for the students' responses to the real problem task and the ambiguous passages. As mentioned, for the real problem task students were given two distinct problems. They were presented with a hypothetical situation and then asked to describe surroundings and possible problems, ask questions they might ask themselves, and speculate how they might have prepared for the problem and on how they might deal with the problem. Again, English writing depends on personal knowledge, so it would have been difficult to speculate on the effect of media (reading, HyperCard, nonHyperCard, in any case). Predictably, no real shifts in the areas analyzed were apparent. As we have suggested, the findings for the ambiguous passages followed the same trend. When students were asked to offer either predictions or questions, there appeared to be no difference across time or projects. It is as if to assess the impact of the hypertext we would need to relate such an assessment to a number of factors -- interest, background knowledge, the topic and approach, technology expertise, and available resources. In addition, we would need to look more closely over time at each individual's experience and learning. Perhaps a case study approach would have been preferable to our approach.

Science tasks

Unlike English, science appeared to rely on more change in knowledge after reading about the subject. Our findings supported this conclusion. Furthermore, the use of hypertext seems to support the acquisition of complex ideas and relations between those ideas (flexibility), although the raw number of ideas generated may decrease. For instance, student S-2 shows the acquisition of specific knowledge about desert climate:

> pre: hot, dry, cactus, desert animals, plants
>
> post: hot during day, cool at night, very unique, many animals and plants, ways of adapting

Knowledge about the desert expanded from general knowledge to an appreciation of it as a unique ecosystem, although the number of ideas expressed remained the same. In the pretest, student S-1 described the desert in a stereotypic fashion indicating a belief that the desert was continuously hot, but by the posttest, student S-1 was aware of the variation that occurs in temperature, and notes the desert is hot during the day but cool at night. In comparing hypertext with nonhypertext, individual differences were considerable with noticable variation from one student to the next (see Table 4).

Table 4

Similar trends were apparent on the "real" problem. Regardless of the nature of their compositions (hypertext or nonhypertext), science students seem to acquire more factual knowledge following any science experience. It is only when these data are examined closely that it could be speculated that for some individuals hypertext seems to stimulate greater flexibility and complexity of ideas. Student S-2, for instance, shows the growth in understanding complexity, the potential problems of being lost on the ocean:

> pre: sense of direction, finding land
>
> post: not knowing where I am, finding my way back, defending myself, weather, ocean currents

The results from the ambiguous passages somewhat paralleled the aforementioned findings for selected science students only -- especially in the question analysis. For selected individuals involved in HyperCard there appeared to be a shift in the kinds of questions pursued. In particular, for students S-4 and S-5, there was a tendency to shift to more why and how questions. At first glance, these findings could support the view that exposure to hypermedia contributes to shifts in thinking and knowledge representation. However, in these cases, it is difficult to determine exact reasons for these findings. The shifts could also be attributed to topic, background knowledge, or the direction of their projects. Although it is uncertain whether hypertext supports access to knowledge in ways that may afford complex and flexible understandings, it is important to note that the text space restrictions and programming demands did not detract from such student engagement and learning.

Concluding remarks

Is hypertext, as Reinking (1994) has suggested, "the harbinger of the post-typographic world?" (p. 24).

Our findings suggest that students view the advantages of the hypertext as allowing a way to architecture a space that affords different engagement for others. The architecture of or engagement with these spaces provides for a juxtaposing of multiple texts that may achieve a crossing of topics that Spiro, Coulson, Feltovich, and Anderson (1988) have espoused as powerful ways of knowing and learning complex knowledge. The multimedia nature of these forms of text being juxtaposed may afford a kind of semiotic engagement that provides students access to multiple symbol systems that allow an ongoing learning through analogies or metaphor. Labbo (1996) has discussed a similar phenomena in exploring young students involvement with multiple forms of representations with computers and their relationship to literacy development.

In educational settings, infatuations with this technology need to be tempered with the realization that the possibilities with any software may be constrained by the setting in which it is used. Several studies (for example, Cochran-Smith, Paris, & Kahn, 1991; Genishi, 1988; Hawkins, 1987; Reilly, 1992) suggest the overriding impact of the classrooms on technology. Sometimes the setting prevents sustained development or constrains the possibilities for technology. For example, access to hypertext may be limited or approaches to the use of hypertext may be constrained by the teacher or by students' expectations or abilities. We emphasize that we were dealing with a unique site and we

were engaged with these same students in other observations. The site afforded students access to technologies at home and at school that allowed them to circumvent the hardware, software, and other demands that have been out of reach for many other sites -- including most computer-based platforms in schools. Likewise, the approach to hypertext was open-ended such that the conventions and norms were not preset.

Although our discussion has focused on HyperCard, we do not think that we are dealing with unique software. In other words, the focus of our investigations was HyperCard, but we could have been exploring other authoring systems that afforded similar possibilities. We suspect that hypertext design features undergird a growing number of authoring systems being used to provide computer users with a palate for interfacing multimedia in juxtaposing fashion -- especially in conjunction with Web development. For this reason, we do not tout a certain software or platform as effective; instead, we see the study as exploring broader issues of learning consistent with past research on learning with media, utilization of multiple sources, notions of literacy learning, and issues of discourse and social development. Hypertext has helped us see the limitations of the norms and conventions in place with traditional text. Although our discussion focuses on 10 students and what they shared and were able to pursue in this unique setting, the students seem to share a history (to which they alluded) that included a tradition of reading and writing that was limiting. The students often seemed to view reading and writing "regular" texts passively, pursuing the recall of ideas rather than the exploration, generation, extension, and reconsideration of thoughts. Although most learning might be conceptualized as multilayered and individualized, most learning with text (whether text production or comprehension) is rather linear, regimented, and nonstylized. It is as if regular texts tended to engender a static rather than dynamic response without regard to their different histories, including cumulations of different dispositions and skills. Hypertext spurred a different orientation to text including ways of exploring ideas and engaging with others. Hypertext appeared to contribute to a breakthrough in how text was viewed and designed by the students as well as different views of how these textual spaces should be approached and used.

In discussing the students' encounters with hypertext, we focused on their shared views rather than on any differences as a result of individual histories. Any creations represent a combination of each student's architectural plans, available resources, and ability to implement these plans with the resources at hand. Certainly, the students had been introduced to hypertext and we provided them adequate technological support to move their plans forward. But we would speculate that individual differences in terms of the students' cumulative literacy experiences are important to trace as we consider the spaces that they architect and help them achieve other design possibilities.

Our interest in hypertext and hypermedia has continued. Subsequent to these follow ups, we have pursued other multimedia platforms (such as video and art) in the ACOT setting and other settings. Our view of technology continues to change as we strive to view it from different vantage points. We are especially interested in a view of literacy that addresses the possibilities from a social semiotic perspective, especially a view that explores the nature and role of these media from the perspective of cultural practices.

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Appendices

Appendix A contains a total listing of student interview questions within categories (the letters A to K show main areas and the letter F with a number show the original order of questions within the final interview format; HC stands for HyperCard, RT for regular text, and B for both). These categories were chosen to organize the data, but were not taken to be mutually exclusive.

Appendix B includes an example of a debriefing interview analysis summary chart.

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Appendix A

Appendix A contains a total listing of student interview questions within categories (the letters A to K show main areas and the letter F with a number show the original order of questions within the final interview format; HC stands for HyperCard, RT for regular text, and B for both). These categories were chosen to organize the data, but were not taken to be mutually exclusive.

A F-02 A F-02 Based on our observations of what you have done, what do you think we will learn about the similarities and differences between HC and RT?

F-06 F-06 What are your views about the sim and diff between doing projects on HC and doing them with RT?

F-09 F-09 What ways do they serve similar or different purposes?

B F-10 B F-10 In what ways do they contribute to learning different things?

F-11 F-11 How would you characterize or describe the type of things you learned from doing HC projects vs RT projects?

C F-03 C F-03 Based on our observations of your finished products, what do you think we will learn abc it the work of putting together these projects?

F-12 F-12 In what ways do you approach HC and RT projects differently?

F-13 F-13 What types of things are easier, more difficult, and why?

D F-14 D F-14 Describe for me how the written text on HC may differ from a regular text.

F-15 F-15 What impact does that have?

F-16 F-16 Describe the use of graphics (pictures) on HC and RT and how they differ and have different impacts.

F-17 F-17 Are there things you do with text in HC that you don't do in RT?

E F-04 E F-04 Use of resources

F-20 F-20 What resources are important for HC vs RT?

F-26 F-26 How do multimedia options assist or complicate the development of a HC stack?

F-23 F-23 Do you have any suggestions as to what other resources you would have liked to have and any comments on the resources that we did provide?

F F-05 F F-0. Interviews and pre-post-test measures

G F-07 G F-07 Tell me about yourself as a writer using HC.

F-08 F-08 Tell me about yourself as a writer using RT.

F-21 F-21 What is the easiest about writing on HC and in RT?

F-22 F-22 What is the most difficult about writing on HC and in RT?

H F-18 H F-18 In what ways are the ideas included in HC vs RT different?

F-27 F-27 Where did most of your ideas come from for the written assignment?

F-28 F-28 Where did most of your ideas come from for the HC assignment?

I F-19 I F-19 In what ways do you think people respond differently to HC vs RT?

J F-24 J F-24 What did you like and dislike about being involved in this project?

F-25 F-25 Any other reactions or suggestions?

K F-01 K F-01 Tell me some of the things you have learned from being in this study.

F-29 F-29 What was the most exciting piece of information that you learned about yourself this week?

F-30 F-30 What was the most exciting piece of information that you learned about science this week?

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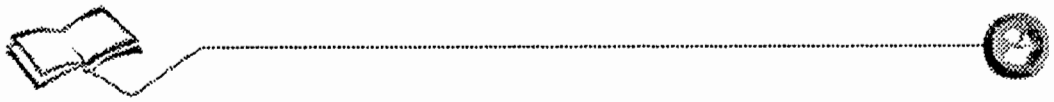

Appendix B

This appendix shows an example of this analysis in the similarities and differences category with each student's utterances centering on attitudes about HyperCard and regular text.

Example of a debriefing interview analysis summary charts

A	F-02	Based on our observations of what you have done, what do you think we will learn about the similarities and differences between HyperCard and regular text?
A	F-06	What are your views about the similarities and differences between doing projects on HyperCard and doing them with regular text?
A	F-09	What ways do they serve similar or different purposes?

		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
more interesting	HC 02	1	1								1
more interesting (story)	HC 02		1								
more interesting	HC 06		1								
interesting	HC 02				1						
keeps you interested	HC 09						1				
want to get the reader interested	HC 06									1	
exciting	HC 06							1			
more exciting	HC 02						1				
can do things a lot better	HC 09							1			
better	HC 02				1						
make them look nicer	HC 09						1				
lot more fun	HC 02								1		
learned more about HyperCard	HC 02									1	
presentation better	HC 06	1									
I like doing them on the regular texts	RT 06			1							
good if you are writing a business letter	RT 09	1									
can't do much on the regular text	RT 09										
not as interesting	RT 06										
regular projects--boring	RT 06										
kind of boring	RT 06										
boring	RT 06										
learned the same amount	B 02										
depending on what you're doing	B 06										

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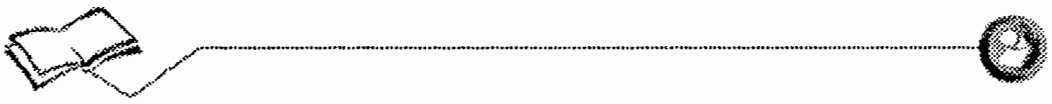

Table 1 Students' view of composition possibilities

(E stands for English, S for Science, HC for HyperCard, RT for regular text, and B for both)

		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
put whole text in	HC				1						
too much text with it then no use	HC	1									
don't have to write	HC										1
too much text--it starts to get boring	HC	1									
can't really do much with the text	HC							1			
text is mostly used to describe	HC	1									
can look at the picture--then look at the text	HC	1									
read the text you understand the picture	HC	1									
can make it look like regular text	HC								1		
text and more	HC								1		
more freedom with the text	HC	1									
has everything that regular text has	HC								1		
it's just not plain	HC		1								
just feed in your information	HC			1							

just have text	RT								1		
only a chunk with the text	RT	1									
text you can just start a new paragraph	RT										
plain text	RT	1									
use a lot more resources using regular project	RT							2			
express yourself	RT	1									
emphasize your own expression	RT	1									
text is traditional	RT	1									
seen it all their lives	RT	1									
all you can do is write this down	RT										
you just write	RT										
write it out	B		1								
can both write text	B								1		
		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
more interesting	HC 02	1	1			1					1
more interesting (story)	HC 02		1								
more interesting	HC 06		1								
interesting	HC 03				1						
keeps you interested	HC 09						1				
want to get the reader interested	HC 06									1	
exciting	HC 06								1		

more exciting	HC 02					1			
can do things a lot better	HC 09						1		
better	HC 02				1				
make them look nicer	HC 09					1			
lot more fun	HC 02							1	
learned more about HyperCard	HC 02								1
presentation better	HC 06	1							
I like doing them on the regular texts	RT 06			1					
good if you are writing a business letter	RT 09	1							
can't do much on the regular text	RT 09							1	
not as interesting	RT 06		1						
regular projects--boring	RT 06								
kind of boring	RT 06			1					
boring RT	RT 06							1	
learned the same amount	B 02								1
depending on what you're doing	B 06						2		

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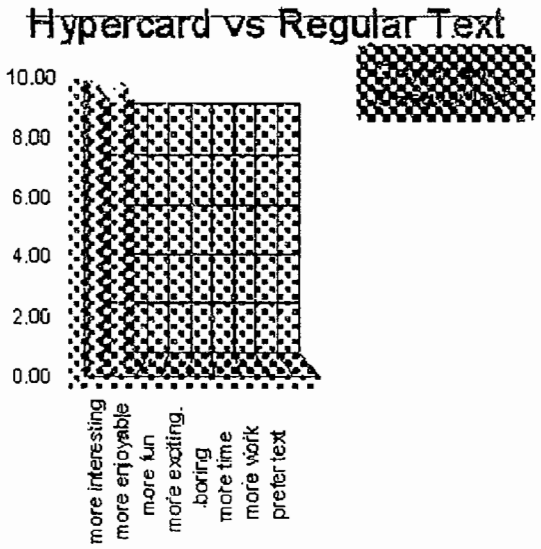
Table 2



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ABSTRACT

Two studies (which followed up a 4-year longitudinal study) examined the impact of hypertext on students' learning in science and English classes. The first study compared the impact of HyperCard stacks and regular textbook presentations of ideas in biology on ninth-grade students assigned to study these materials. Students in the second study, 10 ninth- or tenth-grade students, developed their own HyperCard stacks and regular texts for projects in science and English courses. Data included interviews, videotaped observations of project development, and outcome and process measures. Results indicated that (1) students suggested that the hypertext offered alternatives to standard print texts; (2) students considered HyperCard projects more interesting than conventional texts and assignments; (3) HyperCard texts create by students contained more main ideas, enlisted more illustrations, were more multilayered, and provided clearer links between illustration and the text; (4) hypertext allowed a flexible exploration of ideas across several layers simultaneously; (5) students were motivated to explore its possibilities and were willing to share new findings with other students; and (6) the use of hypertext supported the acquisition of complex ideas and relations between those ideas involving science tasks, but not, apparently, those involving English tasks. Findings suggest that students view the advantages of the hypertext as allowing a way to "architecture" a space that affords different engagement for others. (Contains 16 references and 4 tables of data; appendixes contain a total listing of student interview questions, and an example of a debriefing interview analysis summary chart.) (RS)

Assessing the impact of hypertext on learners' architecture of literacy learning spaces in different disciplines: Follow-up studies

Robert J. Tierney, Ron Kieffer, Kathleen Whalin, Laurie Desai, Antonia Gale Moss, Jo Ellen Harris, and John Hopper

Note: After reading this article, please visit the online discussion forum and share your comments.

Introduction

> Hypertexts remind us that acquiring the discipline to organize one's thoughts into a linear, hierarchical argument is a large part of what we call literate only because the technology of print does not invite other ways to structure and argument, not because that is the natural way we think. Hypertexts provide a means to express ourselves in ways that reflect more directly the complexity of our thinking and the interrelatedness of ideas. (Reinking, 1994, p. 24)

> [Hypertext] allows authors and groups of authors to link information together, create paths through a corpus of related material, annotate existing texts, and create notes that point readers either to bibliographic data or to the body of reference material. Hypertext can allow the creation of an automated encyclopedia of sorts: readers can browse through linked, cross-referenced, annotated text in an orderly but sequential manner. (Yankelovich, Meyrowitz, & van Dam, 1985, p. 18)

As students create texts, they develop spaces for themselves and others. Just as an architect designs spaces in concert with the resources in hand, the environment, and certain goals, learners are constantly engaged in spaces that they create from their resources, frameworks, machinery at hand, and goals. As Vygotsky (1978) suggested, tools such as language or other sign symbols mediate our interactions with the world.

In recent years, with the advent of computers and innovative software, enormous strides have been made in the evolution of textual spaces. Among the most intriguing advances has been the generation of software that allows for the development of texts that are multilayered, multimedia-based, and nonsequential -- text that appears to have the potential for changing how we learn, what we learn, and the nature of community and communication.

Uses of authoring systems

In many ways, the advent of new authoring systems reminds us that literacy is a technology that may support certain ways of knowing over others and support certain conventions or norms of interacting. In particular, with the advent of hypertext, students have access to an authoring tool that allows for the following:

- unfolding ideas through buttons, scrolling, and other means by which authors can stage when and where ideas are displayed;
- creating links between ideas (for example, embeddings) that allow for various forms of relationships: definitional, illustrative, or critical, such that compositions or textual spaces are, as Bolter (1991) has argued, "pulsing networks of ideas";
- providing the dynamic and graphic presentation of ideas by interfacing alphabetic texts with nonlogocentric media such as graphics, animation, or video;
- supporting access to resources and their incorporation in ways that are both malleable and complex;
- furthering a relationship with readers that is collaborative and portfolio-like as stacks

offer multiple layers and multiple explorations and engagements;
- affording asynchronized access to ideas and communications;
- supporting the development of architectured spaces that afford these multidimensional possibilities and a different form of participation by users.

Background

Many of us have been participant observers in the advent of hypertext technologies in conjunction with excursions to Web sites, attempts to create our own sites, or what we have encountered on television (such as multilayered graphic displays used in the evening news or coverage of sporting events). For some of us, the advent of this technology occurred as we worked in school settings -- including settings engaged in exploring the use of technology including HyperCard, hypertext software created by Apple Computer. For example, in our work in the Apple Classroom of Tomorrow (ACOT) we were eyewitnesses to students' introduction to hypertext. In this role, hypertext reoriented our view of the literacy and our views of the impact of technology on learning. We were in year 2 of our 5-year longitudinal study (Tierney et al., 1992) when hypertext was introduced and became the platform of choice for the students' projects.

Students embraced the multimedia and multilayered possibilities and the ability to control the presentation of ideas. As one student suggested, texts were "no longer boring, but dynamic" and conversations around stacks overflowed to recess as students gathered around and critiqued one another's texts with the same attention they might give a video game. In these conversations students assumed roles similar to what one might envision occurring at a meeting of architects -- asking one another, "How did you do that?" "Where did you get that material?" "Can I borrow that?" and "I might modify and use that in my own project."

New learning spaces

As we examined our interviews and observations of students across the 4 years, the advent of hypertext marked a shift toward the development of new learning spaces. We became fascinated with these new spaces and the shifts that they encompassed: the multilayered renditions that were created, the dynamic graphic interfaces enlisted, and the view of audience and meaning making that were sponsored. In years 1 and 2, the students' texts were linear and largely devoid of graphics, whereas in years 3 and 4, graphics had become an integral symbol system within the students' texts; their compositions no longer were one-dimensional, but were multilayered and interactive. Several major shifts occurred as students experimented with these new compositions, especially the graphic interface and multidimensional possibilities that they afforded. The shifts were captured in self-initiated comments and in comments students made when we probed them.

For example, in year 1, interview comments suggested a very linear approach to the text. Comments such as the following were typical:

> It [the computer] helps you to just write down, or type out what you're thinking about, and then lets you get the rough idea out, and then you can just go back and change or add to it. [audio file: 100k]

> It's better to do it on the computer because instead of retyping the whole story you can just add in and correct your mistakes. [audio file: 100k]

With the advent of HyperCard, student descriptions of their approach reflected different goals, different architecture, and different expectations for their text.

> The things that we created weren't really something that could be done on a page. They could be printed out but they still wouldn't be the same, clicking on a button. It wasn't something you could look at; it was something you had to become involved with.

> I wanted to use graphics for this because I don't like to use a lot of text for a project, for anything I do. As I noticed whenever, that is, it tends to get real boring. Even when I have text sometime I like to spruce it up with graphics, at least make it look interesting because I try to make it so that if I had to look at this it wouldn't be something that I would think I had to do. It would be something I was doing because I wanted to. That was one of the concerns when I was doing that paper that we just had. For me it was a bunch of editors and writers and we wanted it to be something that people would enjoy. They would want to read. You can see how it developed.

> But whenever I want a stack I try to make it more interactive so that there's a lot of things that the person who is using them might not see going on. There's variables being changed and carried out and all these things.

Follow-up investigations

In hopes of providing some clarity of the impact of hypertext we decided to pursue some follow up to our interviews in the form of some additional exploratory research -- namely, two investigations.

Follow-up: First probe

Our first probe or investigation (see Galindo, Tierney, and Stowell, 1989, for more details) compared the impact of HyperCard stacks and regular textbook presentations of ideas in biology on students assigned to study these materials. Ninth graders enrolled in the Apple Classroom of Tomorrow were presented with HyperCard stacks and textbook chapters dealing with topics in biology. The textbook chapter represented a traditionally formatted treatment of a topic with subsections together with an occasional illustration; the HyperCard stack afforded multilayered treatments of the same topic (using the same material) in a fashion that used buttons to connect students to illustrations and definitions.

Individual interviews were conducted with the ninth-grade students. In the first part of the interview, the students were asked how they would study the biology chapter and then the HyperCard study guide for a test. This was followed with observations of their behavior as they studied the same information presented in HyperCard and in a biology text. In the second part of the interview, the students were asked what they thought were the advantages and disadvantages of the biology textbook material and HyperCard stacks. In

the third and final part of the interview, the students were asked to compare writing with HyperCard to a regular written assignment.

Analyses of the student interviews were driven by the following questions. First, what is the nature of the communicative framework across the two types of representations of information: a regular textbook and a HyperCard text? Second, what is the nature of the knowledge acquired by studying a regular textbook versus a HyperCard text? We examined statements students offered about what ideas were accessed and how such ideas were linked. Third, what were the students' learning strategies for HyperCard as contrasted with those used with the regular text? In particular, student comments and observed behaviors were examined in hopes of defining the procedures enlisted to access ideas in reading and writing regular text and a HyperCard text.

Follow-up: Second probe

In our second probe or investigation we pursued these issues further. Students in our second investigation developed their own HyperCard stacks and regular texts across parallel topics in two subject areas. As we attempted to study more closely the impact of hypertext on learning processes and outcomes, we enlisted a design, including various measures that might yield more information on the impact of hypertext on the learning of individual students across topics and disciplines (English language arts and science). The following were among the questions that were addressed: In what ways do hypertext-based versus regular text-based compositions vary ? To what extent do these differences vary across individuals of different expertise across selected subject areas (English and science)?

For the second investigation, we enlarged our pool of students involved to 10. All of the students were volunteers and were paid for their participation, which involved extended periods of time each day (3 to 5 hours) across a 3-week period in the summer. During this time, the 10 ninth and tenth graders were involved in developing projects in science or English on different topics. All were competent computer users, but varied in their ability with hypermedia. They included two African American students, two Asian American students, and six Euro-American students who had exposure to hypertext in their classes and some limited use of the software.

Students were assigned randomly to either science or English. Within those subject areas, students were rotated randomly through regular and hypertext-based projects on parallel topics. In geography the topics were "deserts" and "the ocean." In English the topics were "unsolved mysteries" and "unanswered questions." To support the students, a range of resources including books on the topic were available. The students had access to scanning as well as laser-disk technologies, and we enlisted older students to provide technical support (to assist them with their set ups). As with the first investigation, data collection consisted of taped interviews, videotaped observations of project development, the projects themselves, and some outcome and process measures (a measure of shifts in background knowledge and a measure of problem solving).

Data analysis

We pursued various analyses of the transcribed interviews, the compositions themselves, and the learning strategies and outcomes that were prompted. Data for the first

investigation were drawn from our observations and interviews of the students who were asked how they would study the biology book chapter and then the hypertext study guide and were observed doing so. This was followed with an open-ended discussion of what they thought were the advantages and disadvantages of the biology textbook and hypertext study guide as well as what they felt would be the differences involved in composing these texts. In the second investigation, students actually developed hypertext and regular text compositions and responded to a range of measures and a lengthy interview. The interview involved an extensive discussion tied to a total of 30 questions that were asked (see Appendix A for sample of these 30 questions). These questions and the responses were later categorized according to similarities and differences between the two modes: learning outcomes, the approach, observations, the impact of written text, use of resources, interviews and pre- and posttest measures, the writer, ideas, the response of other students, reactions and suggestions about the projects, and personal learnings.

Transcribed student interviews were placed in a Macintosh database management system called FileMaker II. Each student's response to specific questions was sorted and transferred to the same file so that comparisons could be made across students. Student responses to the questions, arranged in the major categories mentioned, were further narrowed to phrases and placed together according to related themes. In addition, comparisons across students and disciplines were charted. (The questions for the second investigation are presented in Appendix A together with a sample of how the analyses were pursued.)

In the second investigation, analyses of the background knowledge, problem solving, and the actual compositions also were pursued. Details of these analyses will be provided with the reporting of results in the following section.

Results

Author to text

The data we acquired from our two investigations confirmed the longitudinal trends that we had observed. In the first investigation, the students suggested that the hypertext offered alternatives to standard print texts ("There were other ways to present ideas" "...drawing pictures...making buttons...going to different stacks") and commented that to do so was more demanding but worth the effort. Similarly, the students involved in our second probe suggested that hypertext afforded them possibilities that traditional text did not. Tables 1 and 2 detail the comments of the students in conjunction with some of the discussion that ensued pertaining to text features. (E stands for English, S for Science, HC for HyperCard, RT for regular text, and B for both.)

Table 1

As the responses in Table 1 indicate, the students view of the composition possibilities differ and seem tied to (1) the graphic interface possibilities (see items highlighted in green) and (2) the perception that the hypertext restricts text (see items highlighted in purple) to what can and should appear on a screen. It should be noted that the brevity was deemed consistent with their desire to focus on the important information (see items highlighted in

orange). The students felt as if there would be greater interest in a project when only important information was given. In contrast, traditional text projects were viewed as merely writing production (see items highlighted in pink). That is, students just write and have plain text, something that they have seen time and time again over their years in school. One of the students involved in the science projects (labeled S-5) described the nature of the text differences:

> You can write in both of them and you can tell a story and you can get your point across but the differences are that you can get your point across in different ways on HyperCard and in text you just write. In HyperCard you can have a picture there with it. You can have buttons. You can have animation even. You don't have to write. [audio file: 200k]

Table 2

As Table 2 shows, when asked about similarities and differences between HyperCard and regular text projects, all 10 students stated that HyperCard is more interesting, more enjoyable, more exciting, or better than more conventional writing assignments. In addition, 5 students described regular text projects as boring. Even though a total of 9 students felt that HyperCard takes more time and requires more work, only 1 student showed a preference for working on regular text projects.

Table 2 (continued)

When students were asked about the approach to projects, prior organization and planning were valued as important components in the implementation of HyperCard projects for 7 out of 10 students [see Table 2 (continued)]. They felt that HyperCard required energy and time resulting in higher quality products. Pride in their accomplishments seemed to follow this greater investment. The creation of buttons, animation, graphics, and fields were elements that increased the difficulty of HyperCard, yet at the same time increased pride in meeting the challenge that HyperCard presented.

Table 3

Overall, all 10 students felt that they could express their ideas in either mode, but HyperCard afforded more possibilities (see Table 3). These included such options as manipulation (see items highlighted in pink), separation of text (see items highlighted in aqua), and animation (see items highlighted in brown). The separating of text required by HyperCard allowed for manipulation of form and increased freedom to experiment with different aspects of presentation (such as space, movement, or switching pictures). To these ends, the students appeared to rely more on past experience for English topics; for science topics students relied heavily on the resources provided, especially graphics.

Advantages of hypertext

In some ways the aforementioned observations of students seemed to suggest what may be obvious attributes or possibilities of hypertext software. Hypertext clearly supports

multilayered multimedia possibilities that are less likely to be engaged by students pursuing traditional text forms.

Certainly, regardless of subject area (English and science), HyperCard texts created by the students contained more main ideas (that is, greater written detail was evident in all conventional texts), enlisted more illustrations, were more multilayered, and provided clearer links between illustrations and the text. In terms of level of detail, the hypertext compositions of the students included less information than the regular text compositions. Again students tended to limit the hypertext to the important ideas that could fit onto a single screen. In addition, it should be noted that rather than relying on text, students involved with HyperCard projects were able to develop a sequence of events by the movement from card to card, and were thus able to avoid overly detailed texts.

When English and science were compared, the hypertext compositions produced in response to English-related topics were far more detailed and elaborate than were the science texts, which were primarily a listing of facts. Science pieces, both conventional and HyperCard, contained noticeably more main ideas than did English.

Artwork and illustrations were far more apparent in the science projects and provided a larger contribution to the text than did the illustrations in the English projects. Again, this may have been a reflection of the nature of the science content All the students who used illustrations appeared to incorporate them in a logical sequence. Science projects not only discussed desert animals, they provided an immediate illustration of the animal it its natural habitat. The science HyperCard projects also appeared to be more multilayered than did their English counterparts; the science projects appeared to focus on the delivery and explanation of ideas. Alternatively, English pieces contained far more supporting ideas and appeared to emphasize the unfolding of their text to heighten suspense. English texts used visuals to orient the user or reader to a certain perspective as well as to heighten involvement. An English HyperCard project established a link between the third-person voice and the first-person view of the illustrations, providing a richer experience for the reader.

Author-reader and student learning

In discussing technology and learning -- especially with the World Wide Web -- Owston (1997) emphasizes that "no medium, in and of itself, is likely to improve learning.... The key to the Web appears to lie in how effectively the medium is exploited" (p. 29). We would posit that the Web is an extension of hypertext and moreover would suggest that hypertext as a learning and communication tool also is contingent on how well its features lend themselves to exploitation. The students we interviewed and observed seem to suggest that this tool affords opportunities to engage in ways of connecting ideas that otherwise would have been less possible with traditional texts.

As we suggested in the introduction, hypertext allows for flexible exploration of ideas across several layers simultaneously. The set of navigational tools available to the developer allow for the development of intertextual linkages that suggest a view of the reader's engagement that is both multimodal and multilayered as well as menu-like. Likewise, readers' involvement and choices are apt to expand as they are faced with decisions that they are expected to initiate. Indeed, the role of readers may increase the

likelihood of reader engagement that is less acquiescing.

The multimedia possibilities appear to serve a motivational function as well as alternative ways of learning that afford the kind of learning by metaphor or semioses that Siegel (in press), Siegel and Carey (1989), and Labbo (1996) have suggested. For students across both investigations, a combination of reading, viewing, and listening, and aspects of a HyperCard presentation seemed preferable to regular text presentation. They felt that multimedia presentations contribute to the respondents' engagement with the product (i.e., they will read it all, are more drawn to it, pay attention more, listen more, and watch it more), thus increasing the possibility of personal understanding [see Table 3 (continued)]. Student S-5 supports these ideas with the following response:

> Text just -- when you learn something new in the text I don't think it's as interesting. Now in HyperCard I think that that is really good because when people talk I like it a lot when you can see something like when they have an animation. I think that really catches your attention because you see something on the screen and you're like what is that? It's really cute and it gets your attention and with text you're just like oh, and you have to sit and listen and I can't sit and listen for a long period of time because then I'm like -- I kind of want to drift off but with HyperCard there are so many ways that you can catch their attention and so it makes you remember more.

Table 3 (continued)

Above all, HyperCard was considered more enjoyable to students because it was novel; it drew attention and thus caused the students to investigate its operation. Students seemed moved to explore its possibilities and were willing to share new findings with other students. Regular text projects, however, were considered less exciting because they were more traditional and less innovative, and the students had used the mode for many years.

Certainly, hypertext and the Web may offer users the advantage of working in a genre that gives the author more license to create new forms of discourse. As Nyce (1987) suggested, hypertext has yet to have in place established conventions. He stated, "how knowledge should be represented and created remains an open question" (p. 186).

Indeed, our students' speculations concur with findings from our attempts to measure shifts in knowledge and problem solving more directly.

Impact on students

Assessing the impact on learning outcomes versus self-reports of their impact prompted us to pursue the difficult job of examining changes in learning through the enlistment of several additional measures. To these ends, we pursued some additional data collection beyond our interviews· student responses to (1) a "real problem," (2) an ambiguous text, and (3) a background knowledge assessment. These tasks were removed from the project itself, in that they were asked out of the context of the HyperCard or nonHyperCard projects, and thus were analyzed separately. For the knowledge assessment, the students primarily listed everything they could remember about the assigned topic; however, several students wrote in sentence form and one or two wrote more elaborate paragraphs. The

nature of the prompts in the real problem called for entire sentences and questions, and, as a result, the students presented a sequence of topic-related statements, often in the form of a question. Two researchers evaluated each student's responses in terms of number of ideas, complexity, and flexibility. Inter-rater reliability was judged to be approximately 90%. Analyzed characteristics were defined as follows:

x number of ideas:	number of separate ideas expressed by students
x complexity:	ideas were elaborated on by the student -- ideas were clarified further -- for example, subordinate clauses and adjectives were present. Complexity was rated 0, 1 (at least 1 instance of complexity), or 2 (2 or more instances)
x flexibility:	classes of ideas were identified by researchers, animals, plants, or survival, to name a few

Ambiguous passages were used to measure the impact of hypermedia on an individual's ability to generate and link ideas. After reading the selected passages, 10 students responded in writing to four questions: (1) What questions do you have about this passage? (2) What do you think is happening? (3) What do you think happened just prior to this? and (4) What do you think happened just after this? The open-ended quality of each passage allowed for multiple interpretations and varied responses across individuals. In the English topic group, there were three distinct passages administered during the beginning, middle, and end of the study. In the science topic group, a total of six tasks were used involving four distinct ambiguous passages. Prior to and following the first project (HyperCard and nonHyperCard), the same passage about deserts was read and responded to by the students allowing a pre- and posttest measure. The third task involved a different ambiguous passage on deserts. This sequence was repeated using the same ocean passage for the fourth and fifth tasks followed by a different final ambiguous passage on oceans. We focused primarily at the two instances when the passages were repeated. Our overall purpose for administering these tasks was to look for shifts in the presentation of ideas and how the ideas were related to one another.

After reviewing the students work, we became particularly interested in the difficulty of questions asked, the amount of students' ideas, the links between ideas, and the flexibility or classes of ideas represented in each student's responses. As a result, the analysis of students' responses to ambiguous passages followed two directions: an ideational analysis of responses using three categories: (1) total number of ideas, (2) complexity of ideas, and (3) flexibility; and number of classes of ideas. Again, these three characteristics were examined in terms of differences between HyperCard and nonHyperCard measures.

Our analyses of these data created more questions than answers. English and science, not surprisingly, seem to reflect two very different disciplines and hence ways to approach tasks. Therefore, English and science tasks will be discussed separately.

English tasks

By the nature of the content area of English, there are no real "facts" to acquire, and the nature of the task itself depends on one's own prior experience and knowledge. Shifts in the

areas considered might depend more on the involvement of the writer than on any experiences gained through reading or the use of media (HyperCard, nonHyperCard). The measures used might fail to capture changes that occurred in the individual student. A description that states the existence of complexity, for instance, fails to measure the subtle differences between student E-1's pre- and post-responses to "answered questions":

> pre: Questions are the only reasons we are willing to go on living from day to day.
>
> post: Makes you feel conscious about the world you live in.

The same trends were apparent for the students' responses to the real problem task and the ambiguous passages. As mentioned, for the real problem task students were given two distinct problems. They were presented with a hypothetical situation and then asked to describe surroundings and possible problems, ask questions they might ask themselves, and speculate how they might have prepared for the problem and on how they might deal with the problem. Again, English writing depends on personal knowledge, so it would have been difficult to speculate on the effect of media (reading, HyperCard, nonHyperCard, in any case). Predictably, no real shifts in the areas analyzed were apparent. As we have suggested, the findings for the ambiguous passages followed the same trend. When students were asked to offer either predictions or questions, there appeared to be no difference across time or projects. It is as if to assess the impact of the hypertext we would need to relate such an assessment to a number of factors -- interest, background knowledge, the topic and approach, technology expertise, and available resources. In addition, we would need to look more closely over time at each individual's experience and learning. Perhaps a case study approach would have been preferable to our approach.

Science tasks

Unlike English, science appeared to rely on more change in knowledge after reading about the subject. Our findings supported this conclusion. Furthermore, the use of hypertext seems to support the acquisition of complex ideas and relations between those ideas (flexibility), although the raw number of ideas generated may decrease. For instance, student S-2 shows the acquisition of specific knowledge about desert climate:

> pre: hot, dry, cactus, desert animals, plants
>
> post: hot during day, cool at night, very unique, many animals and plants, ways of adapting

Knowledge about the desert expanded from general knowledge to an appreciation of it as a unique ecosystem, although the number of ideas expressed remained the same. In the pretest, student S-1 described the desert in a stereotypic fashion indicating a belief that the desert was continuously hot, but by the posttest, student S-1 was aware of the variation that occurs in temperature, and notes the desert is hot during the day but cool at night. In comparing hypertext with nonhypertext, individual differences were considerable with noticable variation from one student to the next (see Table 4).

Table 4

Similar trends were apparent on the "real" problem. Regardless of the nature of their compositions (hypertext or nonhypertext), science students seem to acquire more factual knowledge following any science experience. It is only when these data are examined closely that it could be speculated that for some individuals hypertext seems to stimulate greater flexibility and complexity of ideas. Student S-2, for instance, shows the growth in understanding complexity, the potential problems of being lost on the ocean:

> pre: sense of direction, finding land
>
> post: not knowing where I am, finding my way back, defending myself, weather, ocean currents

The results from the ambiguous passages somewhat paralleled the aforementioned findings for selected science students only -- especially in the question analysis. For selected individuals involved in HyperCard there appeared to be a shift in the kinds of questions pursued. In particular, for students S-4 and S-5, there was a tendency to shift to more why and how questions. At first glance, these findings could support the view that exposure to hypermedia contributes to shifts in thinking and knowledge representation. However, in these cases, it is difficult to determine exact reasons for these findings. The shifts could also be attributed to topic, background knowledge, or the direction of their projects. Although it is uncertain whether hypertext supports access to knowledge in ways that may afford complex and flexible understandings, it is important to note that the text space restrictions and programming demands did not detract from such student engagement and learning.

Concluding remarks

Is hypertext, as Reinking (1994) has suggested, "the harbinger of the post-typographic world?" (p. 24).

Our findings suggest that students view the advantages of the hypertext as allowing a way to architecture a space that affords different engagement for others. The architecture of or engagement with these spaces provides for a juxtaposing of multiple texts that may achieve a crossing of topics that Spiro, Coulson, Feltovich, and Anderson (1988) have espoused as powerful ways of knowing and learning complex knowledge. The multimedia nature of these forms of text being juxtaposed may afford a kind of semiotic engagement that provides students access to multiple symbol systems that allow an ongoing learning through analogies or metaphor. Labbo (1996) has discussed a similar phenomena in exploring young students involvement with multiple forms of representations with computers and their relationship to literacy development.

In educational settings, infatuations with this technology need to be tempered with the realization that the possibilities with any software may be constrained by the setting in which it is used. Several studies (for example, Cochran-Smith, Paris, & Kahn, 1991; Genishi, 1988; Hawkins, 1987; Reilly, 1992) suggest the overriding impact of the classrooms on technology. Sometimes the setting prevents sustained development or constrains the possibilities for technology. For example, access to hypertext may be limited or approaches to the use of hypertext may be constrained by the teacher or by students' expectations or abilities. We emphasize that we were dealing with a unique site and we

were engaged with these same students in other observations. The site afforded students access to technologies at home and at school that allowed them to circumvent the hardware, software, and other demands that have been out of reach for many other sites -- including most computer-based platforms in schools. Likewise, the approach to hypertext was open-ended such that the conventions and norms were not preset.

Although our discussion has focused on HyperCard, we do not think that we are dealing with unique software. In other words, the focus of our investigations was HyperCard, but we could have been exploring other authoring systems that afforded similar possibilities. We suspect that hypertext design features undergird a growing number of authoring systems being used to provide computer users with a palate for interfacing multimedia in juxtaposing fashion -- especially in conjunction with Web development. For this reason, we do not tout a certain software or platform as effective; instead, we see the study as exploring broader issues of learning consistent with past research on learning with media, utilization of multiple sources, notions of literacy learning, and issues of discourse and social development. Hypertext has helped us see the limitations of the norms and conventions in place with traditional text. Although our discussion focuses on 10 students and what they shared and were able to pursue in this unique setting, the students seem to share a history (to which they alluded) that included a tradition of reading and writing that was limiting. The students often seemed to view reading and writing "regular" texts passively, pursuing the recall of ideas rather than the exploration, generation, extension, and reconsideration of thoughts. Although most learning might be conceptualized as multilayered and individualized, most learning with text (whether text production or comprehension) is rather linear, regimented, and nonstylized. It is as if regular texts tended to engender a static rather than dynamic response without regard to their different histories, including cumulations of different dispositions and skills. Hypertext spurred a different orientation to text including ways of exploring ideas and engaging with others. Hypertext appeared to contribute to a breakthrough in how text was viewed and designed by the students as well as different views of how these textual spaces should be approached and used.

In discussing the students' encounters with hypertext, we focused on their shared views rather than on any differences as a result of individual histories. Any creations represent a combination of each student's architectural plans, available resources, and ability to implement these plans with the resources at hand. Certainly, the students had been introduced to hypertext and we provided them adequate technological support to move their plans forward. But we would speculate that individual differences in terms of the students' cumulative literacy experiences are important to trace as we consider the spaces that they architect and help them achieve other design possibilities.

Our interest in hypertext and hypermedia has continued. Subsequent to these follow ups, we have pursued other multimedia platforms (such as video and art) in the ACOT setting and other settings. Our view of technology continues to change as we strive to view it from different vantage points. We are especially interested in a view of literacy that addresses the possibilities from a social semiotic perspective, especially a view that explores the nature and role of these media from the perspective of cultural practices.

Note: Please visit the online discussion forum and share your comments about this article.

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Appendices

Appendix A contains a total listing of student interview questions within categories (the letters A to K show main areas and the letter F with a number show the original order of questions within the final interview format; HC stands for HyperCard, RT for regular text, and B for both). These categories were chosen to organize the data, but were not taken to be mutually exclusive.

Appendix B includes an example of a debriefing interview analysis summary chart.

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Appendix A

Appendix A contains a total listing of student interview questions within categories (the letters A to K show main areas and the letter F with a number show the original order of questions within the final interview format; HC stands for HyperCard, RT for regular text, and B for both). These categories were chosen to organize the data, but were not taken to be mutually exclusive.

A F-02 A F-02 Based on our observations of what you have done, what do you think we will learn about the similarities and differences between HC and RT?

F-06 F-06 What are your views about the sim and diff between doing projects on HC and doing them with RT?

F-09 F-09 What ways do they serve similar or different purposes?

B F-10 B F-10 In what ways do they contribute to learning different things?

F-11 F-11 How would you characterize or describe the type of things you learned from doing HC projects vs RT projects?

C F-03 C F-03 Based on our observations of your finished products, what do you think we will learn abc it the work of putting together these projects?

F-12 F-12 In what ways do you approach HC and RT projects differently?

F-13 F-13 What types of things are easier, more difficult, and why?

D F-14 D F-14 Describe for me how the written text on HC may differ from a regular text.

F-15 F-15 What impact does that have?

F-16 F-16 Describe the use of graphics (pictures) on HC and RT and how they differ and have different impacts.

F-17 F-17 Are there things you do with text in HC that you don't do in RT?

E F-04 E F-04 Use of resources

F-20 F-20 What resources are important for HC vs RT?

F-26 F-26 How do multimedia options assist or complicate the development of a HC stack?

F-23 F-23 Do you have any suggestions as to what other resources you would have liked to have and any comments on the resources that we did provide?

F F-05 F F-0. Interviews and pre-post-test measures

G F-07 G F-07 Tell me about yourself as a writer using HC.

F-08 F-08 Tell me about yourself as a writer using RT.

F-21 F-21 What is the easiest about writing on HC and in RT?

F-22 F-22 What is the most difficult about writing on HC and in RT?

H F-18 H F-18 In what ways are the ideas included in HC vs RT different?

F-27 F-27 Where did most of your ideas come from for the written assignment?

F-28 F-28 Where did most of your ideas come from for the HC assignment?

I F-19 I F-19 In what ways do you think people respond differently to HC vs RT?

J F-24 J F-24 What did you like and dislike about being involved in this project?

F-25 F-25 Any other reactions or suggestions?

K F-01 K F-01 Tell me some of the things you have learned from being in this study.

F-29 F-29 What was the most exciting piece of information that you learned about yourself this week?

F-30 F-30 What was the most exciting piece of information that you learned about science this week?

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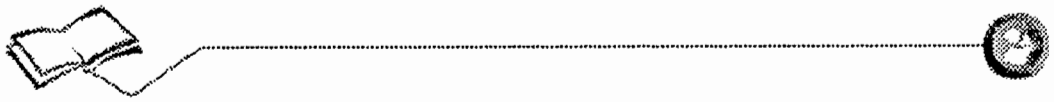

Appendix B

This appendix shows an example of this analysis in the similarities and differences category with each student's utterances centering on attitudes about HyperCard and regular text.

Example of a debriefing interview analysis summary charts

A	F-02	Based on our observations of what you have done, what do you think we will learn about the similarities and differences between HyperCard and regular text?
A	F-06	What are your views about the similarities and differences between doing projects on HyperCard and doing them with regular text?
A	F-09	What ways do they serve similar or different purposes?

		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
more interesting	HC 02	1	1								1
more interesting (story)	HC 02		1								
more interesting	HC 06		1								
interesting	HC 02				1						
keeps you interested	HC 09						1				
want to get the reader interested	HC 06									1	
exciting	HC 06							1			
more exciting	HC 02						1				
can do things a lot better	HC 09							1			
better	HC 02				1						
make them look nicer	HC 09						1				
lot more fun	HC 02								1		
learned more about HyperCard	HC 02									1	
presentation better	HC 06	1									
I like doing them on the regular texts	RT 06			1							
good if you are writing a business letter	RT 09	1									
can't do much on the regular text	RT 09										
not as interesting	RT 06										
regular projects--boring	RT 06										
kind of boring	RT 06										
boring	RT 06										
learned the same amount	B 02										
depending on what you're doing	B 06										

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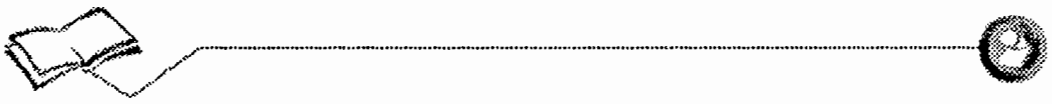

Table 1 Students' view of composition possibilities

(E stands for English, S for Science, HC for HyperCard, RT for regular text, and B for both)

		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
put whole text in	HC				1						
too much text with it then no use	HC	1									
don't have to write	HC										1
too much text--it starts to get boring	HC	1									
can't really do much with the text	HC							1			
text is mostly used to describe	HC	1									
can look at the picture--then look at the text	HC	1									
read the text you understand the picture	HC	1									
can make it look like regular text	HC								1		
text and more	HC								1		
more freedom with the text	HC	1									
has everything that regular text has	HC								1		
it's just not plain	HC		1								
just feed in your information	HC			1							

just have text	RT								1		
only a chunk with the text	RT	1									
text you can just start a new paragraph	RT										
plain text	RT	1									
use a lot more resources using regular project	RT							2			
express yourself	RT	1									
emphasize your own expression	RT	1									
text is traditional	RT	1									
seen it all their lives	RT	1									
all you can do is write this down	RT										
you just write	RT										
write it out	B		1								
can both write text	B								1		
		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
more interesting	HC 02	1	1			1					1
more interesting (story)	HC 02		1								
more interesting	HC 06		1								
interesting	HC 03				1						
keeps you interested	HC 09						1				
want to get the reader interested	HC 06									1	
exciting	HC 06								1		

more exciting	HC 02					1			
can do things a lot better	HC 09						1		
better	HC 02				1				
make them look nicer	HC 09					1			
lot more fun	HC 02							1	
learned more about HyperCard	HC 02								1
presentation better	HC 06	1							
I like doing them on the regular texts	RT 06			1					
good if you are writing a business letter	RT 09	1							
can't do much on the regular text	RT 09							1	
not as interesting	RT 06		1						
regular projects--boring	RT 06								
kind of boring	RT 06			1					
boring RT	RT 06							1	
learned the same amount	B 02								1
depending on what you're doing	B 06						2		

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Table 2

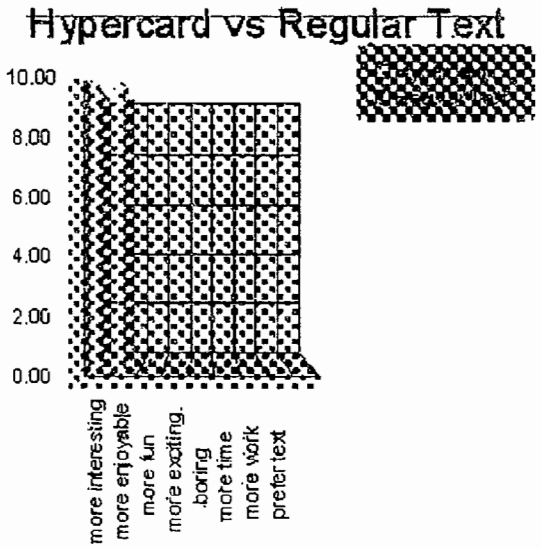

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Table 2 (continued) Students' view of similarities and differences between HyperCard and regular text projects
(E stands for English, S for Science, HC for HyperCard, RT for regular text, and B for both)

		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
organized	HC						1				
got to do more planning	HC		1								
organization is a little different	HC	1									
prepare what sequence I want the stacks to be	HC					1					
usually don't think of whole project before start	HC						1				
take about an hour -- go somewhere off on my own	HC							1			
think about all the possibilities	HC							3			
start some way	HC						1				
think about how you want it to look	HC						1				
know what you're going to do before you start	HC				1						
just start--end up messing up somewhere	HC				1						
get more ideas of what you want to do	HC										1
read everything	HC						1				
make your notes	HC						1				
take it step-by-step	HC				1	1					
change it around	HC						1				
do all the things	HC	1									
do all the steps before I'd put it in	HC	1									

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Table 3 Students' views of the ability to express ideas

(E stands for English, S for Science, HC for HyperCard, RT for regular text, and B for both)

		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
lot of space	HC				1						
more capabilities	HC					1					
lot of possibilities	HC			1			1				
less problems	HC								1		
do a lot more things	HC										2
showing a different view of things	HC		1								
lot of options	HC						1	1			
has more expansions	HC								1		
has more learning abilities	HC								3		
so many different choices	HC										1
extension never stop	HC								1		
separate it	HC						2				
doesn't have to be all together	HC						1				
can manipulate your projects around	HC	1									
margins that you can see what you can do	HC				1						
more creative	HC	2					1	1			
different way of presenting ideas	B									1	
get your point across	B										1

think about how presenting ideas	B									1	
more ideas	B				1						
getting down what you think	B			1							
animation	HC	2	1		3	1	1	1	4		
animation (easier)	HC						1				
animation (like the best)	HC							1			
just have the animation right there	HC										1
animation button--turning pages like a story	HC		1								
tend to do animation that summarizes the story	HC	1									
you can animate the graphics	HC	1									
see better with animation	HC	1									
it's better when you have animation & pictures	HC		1								
creating with animation	HC					1					
people expect you to animate it	HC	1									
only useful purpose is for animation	HC	1									
can have things move	HC			1		1					
can move things around	HC										
have to move	HC				2						
explain why to move it	HC				1						
motions	HC	1					1				
visual effects	HC		1								
couldn't express all your feelings in animation	HC	1									

can't have no motions	RT							1			
people aren't going to expect you to animate it	RT	1									
can move it any way you want to	RT	1									
		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
add pictures	HC		1		1						
change it to the picture style	HC				1						
put pictures beside it	HC										3
can show pictures--when you write it out	HC		1		1					1	
can have them change pictures	HC			2							
try to fit the picture in the paragraphs	HC						1				
picture that will have words to it like a movie	HC								1		
just have a picture with writing beside it	HC										1
switch pictures within seconds	HC			1							
using pictures is a little easier	HC			1							
makes you look at it where it is with the text	HC						1				
see the picture you just want to read the text	HC						1				
being able to use pictures	HC							1			
best thing is when a graphic moves	HC				1						
makes me happy (when graphics move)	HC				1						

can put art with my writing	HC		1		
one of the most important resources--graphics	HC	2			
put our graphics in with it	HC			1	
graphics plus--so many different graphics	HC				
express it through graphics	HC	1			
text and graphics at the same time	HC	1			
easier to do graphics	HC		1		

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Table 3 (continued) Students' views of the ability to express ideas

(E stands for English, S for Science, HC for HyperCard, RT for regular text, and B for both)

		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
read it -- watch it -- learn something	HC	1									
they'll read it all	HC						1				
breaks it down and makes you read it	HC									1	
makes you remember more	HC										1
make sure -- people remember what talking about	HC										1
memorize it more than a big sheet of writing	HC									1	
listened more or watched it more	HC										1
catches you attention	HC										1
more drawn to	HC		1								
good when people talk -- can see something	HC										2
reading a story and -- have pictures beside it	HC	1									
it gets people to read it	HC						2				
guess the reader can enjoy it more	HC					1					
something to look at while they're talking	HC										1
let them read the story themselves	HC		2								

		E1	E2	E3	E4	E5	S1	S2	S3	S4	S5
let them click on the buttons	HC		1								
many ways that you can catch their attention	HC										1
can pay attention more	HC						2				
want to present as little as possible	HC										1
sort of short and it's easy to understand	HC							2			
as much information as possible	HC										1
it's good for the eyes maybe	HC						1				
kind of choppy	HC							1			
don't say something that's not important	HC										1
have the computer talk for me	HC								1		
it's just read it	RT										1
just act like they're reading it	RT						1				
can imagine your own characters	RT	1									
read something -- not going to remember	RT										1

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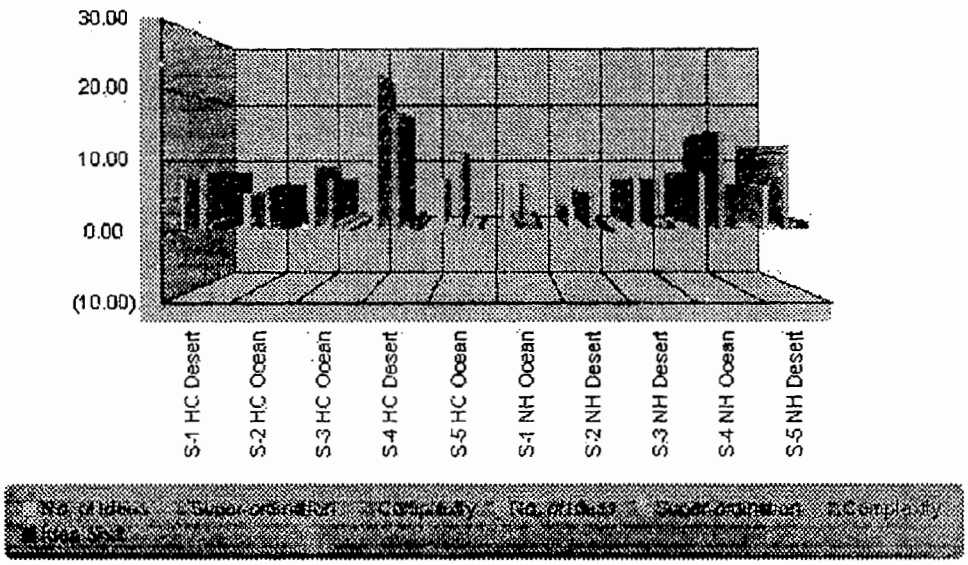
Link to Table 4

Ideational Analysis of Background Knowledge

Assessment for Science



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